Characteristics and Conservation of a Trophy Alligator Gar Population in the Middle Trinity River, Texas

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Abstract: The middle Trinity River in Texas supports one of the premier trophy alligator gar (*Atractosteus spatula*) fisheries in the world. Published data on alligator gar life history and population characteristics are sparse, yet these data are needed to inform conservation and management. Using data from over 850 fish collected between 2007 and 2014, we described the size structure, population abundance, angler exploitation, and vital rates of this unique population. Collection of fish relied heavily on angler cooperators and included a three-year mark-recapture effort and the removal of sagittal otoliths from fish harvested by bow anglers. Size structure and population abundance data revealed why this population supports such a popular fishery. Size structure was broad (fish ranged from 46 to 241 cm) and trophy-sized alligator gar (> 180 cm) comprised more than 23% of the sample. Density of alligator gar was almost twice that reported for other systems and annual estimates of abundance of fish ≥107 cm ranged from 7903 to 8413 fish (26 fish river-km^{-1}; 0.8 fish ha^{-1}). Annual total mortality was estimated to be 8.5% of which angler exploitation did not exceed 5%. Individual length at age was highly variable; however, growth curves were generally similar to previous studies. While more restrictive regulations (e.g., harvest quotas or permits) may be required in the future if angling pressure increases, the middle Trinity River currently provides a sustainable trophy alligator gar fishery.

Key words: Atractosteus spatula, alligator gar, life history, population estimate, exploitation, size structure

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Following decades of persecution and population declines across much of its historic range, the alligator gar (*Atractosteus spatula*) has recently become the subject of renewed interest as a sport fish. The 2008 designation of alligator gar as "vulnerable" by the American Fisheries Society (AFS; Jelks et al. 2008) has prompted fish and wildlife agencies to focus conservation and research activities on the species. In addition, the Southern Division of the AFS formed an Alligator Gar Technical Committee in 2009 to share information and foster cooperation among researchers in the region. Recently, seven states have restricted or prohibited harvest of alligator gar (Binion et al. 2015). In Texas, alligator gar had been unregulated, but increased popularity of fishing for trophy alligator gar led the Texas Parks and Wildlife Department (TPWD) in 2009 to implement a precautionary statewide one fish per day bag limit to provide some protection to this potentially vulnerable species. The one fish per day bag limit was considered a first step toward managing alligator gar while data were gathered both in Texas and throughout the species range.

Data on alligator gar life history and population characteristics are sparse. Historically, alligator gar occurred throughout most of the southeastern United States and Mexico, but habitat loss and overexploitation have significantly reduced their range (Jelks et al. 2008). Alligator gar remain abundant in Texas and Louisiana and are mostly found in large river systems, their associated reservoirs, and coastal estuaries where successful spawning and reproduction is thought to occur during large flood pulses over terrestrial vegetation (Inebnit 2009, Kluender 2011, Buckmeier et al. 2013). Alligator gar are long-lived, slow to mature, highly fecund, and exhibit highly variable recruitment associated with unstable environments (Ferrara 2001), all characteristic of species with a periodic life history strategy as defined by Winemiller and Rose (1992). Periodic life history strategist species can be vulnerable to population declines caused by overfishing (Parent and Schrimi 1995, Boreman 1997, Jennings et al. 1998). Studies by Ferrara (2001) and DiBenedetto (2009) previously provided basic life history data of alligator gar in coastal Alabama and Louisiana, respectively. Binion et al. (2015) provided some of the first peer-reviewed population dynamics and vital-rate estimates for alligator gar in the United States. That study focused on a Texas reservoir population of alligator gar; however, river populations may have different vital rates and population characteristics.

The Trinity River in Texas appears to support one of the premier trophy alligator gar fisheries in the world. Anglers fishing the Trinity River routinely report catching alligator gar in excess of 70 kg and catching gar greater than 100 kg is not uncommon. This popular alligator gar fishery has become internationally known and has been the subject of numerous nature-based television programs airing on the National Geographic, Discovery, Animal Planet, and History channels. The river is popular for both rod-and-reel angling and bowfishing (Bennett and Bonds 2012). Prior to this study, alligator gar population and harvest data were lacking in the Trinity River system, and information on the fish was limited to anecdotal reports. Because of the importance and growth in popularity of this gar fishery, our goal was to estimate the population characteristics and status of alligator gar in the middle Trinity River to inform current and future management. Specific objectives of this project included estimation of: 1) size structure; 2) population abundance; 3) angler exploitation; and 4) vital rates (i.e., longevity, mortality, and growth).

Methods

Study Area

Our study was focused on an approximately 325-km reach of the middle Trinity River, Texas, bounded on the upstream end by Highway 31 near Dallas and on the downstream end by Highway 190 near the upper end of Livingston Reservoir (Figure 1). This reach represents most of the fishable water (~10,700 ha) designated as the upper Trinity River by Bennett and Bonds (2012) but excludes headwater areas. The Trinity River is primarily free-flowing in this reach with the exception of an incomplete lock and dam near the State Highway 7 road crossing (near Crockett, Texas) that likely functions as a partial fish barrier, especially to upstream movement. Although this reach is located near several large population centers, there are only three public boat ramps, located near the top and bottom of our study reach (Figure 1).

Collection / Sampling

Data from over 850 individual alligator gar were obtained between 2007 and 2014 for use in this study, mostly from angler cooperators. Size structure, population abundance, and angler exploitation (i.e., from mark and recapture) data were collected through fish captured by Kirkland's Gar Fishing Guide Service. Age samples of alligator gar were predominantly collected from

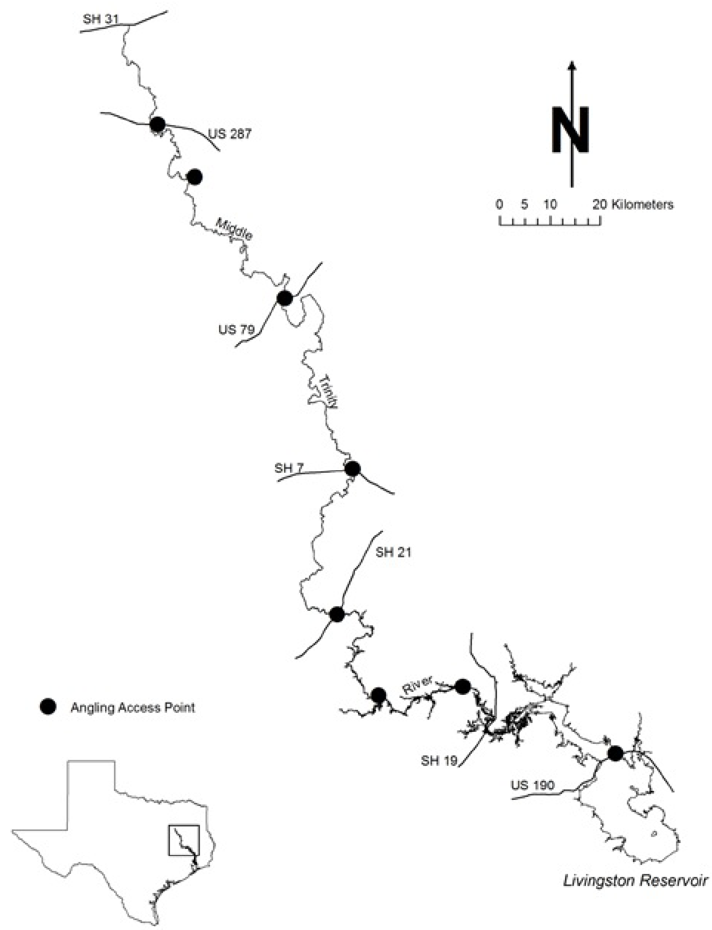

Figure 1. Map of the middle Trinity River study area including the distribution of angling areas where alligator gar were captured by rod and reel anglers for the mark-recapture study. With the exception of public boat ramps at U.S. Highway 287, U.S. Highway 190, and State Highway (SH) 19, all other access points were private or unimproved.

bowfishing tournaments and bowfishing cooperators ($n=105$; Bennett and Bonds 2012), and by state personnel using angling and gillnets ($n=14$). Alligator gar data collection was broadly distributed spatially throughout the study reach.

Size Structure, Population Abundance, and Angler Exploitation

From August 2007 through June 2010, alligator gar caught by rod-and-reel anglers fishing with Kirkland's Gar Fishing Guide Service were tagged (at first capture) with an individually numbered T-bar anchor tag (FD-94; Floy Tag and Manufacturing, Inc.; Seattle, Washington) near the dorsal fin (Buckmeier and Reeves 2012) and measured for total length (TL). Following tagging, alligator gar were released near their capture location. When fish were recaptured by clients of the guide service, they were measured and tag numbers were recorded. Each year, angling occurred several days per week between April and November in eight primary ar-

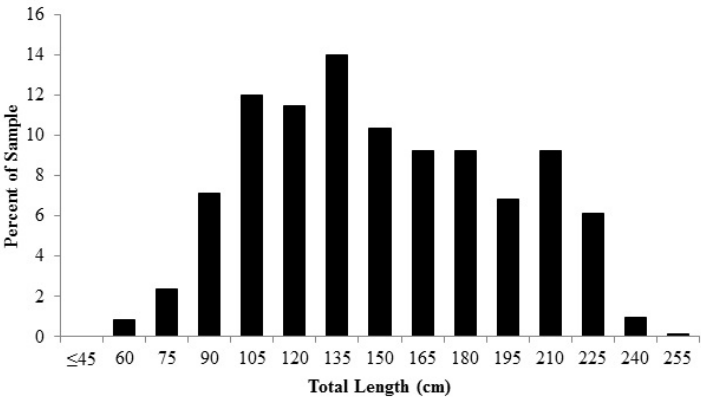

Figure 2. Length frequency (15-mm groups) of alligator gar ($n = 715$) captured in the middle Trinity River, Texas, from August 2007 through June 2010 using rod and reel angling.

eas dispersed throughout the study reach (Figure 1); angling and tagging by the guide service did not occur during winter months. These fish were caught using large baits (typically > 0.5-kg cut fish), and after examination of the length frequency (Figure 2), alligator gar < 107 cm TL were not considered fully recruited to the gear.

Size structure of alligator gar was estimated by pooling angler-caught fish across years ($n = 715$). Although fish < 107 cm were not fully represented, they were included in our length frequency analyses to document presence. Total length of some fish ($n = 75$) was estimated by the guide because fish were immediately released at the boat and were not landed. Although these estimates could be underestimated or overestimated by as much as 15 cm, they were included because such error would only place a fish in an adjacent 15 cm length category and should not affect the overall shape of the size distribution.

Population abundance for our study reach was estimated using a Schnabel multiple census estimator (Seber 1982). Each census period represented about 1 month of pooled fishing effort ($n = 18$ periods); winter months were not included because no fishing occurred. For each census period, numbers of marked fish were adjusted for tag loss and hooking mortality. Although Buckmeier and Reeves (2012) found anchor tag loss was minimal in the first year, we assumed a 10% annual tag loss as a conservative estimate because retention of anchor tags typically decreases substantially after the first year (e.g., Timmons and Howell 1995). We also adjusted the number of tags at large by assuming 20% of fish from 107 to 152 cm died from hooking and handling stress based on incidental hooking mortality previously observed during TPWD collections of alligator gar (TPWD; unpublished data). Hooking mortality on fish larger than 152 cm was assumed negligible as none has been documented for fish of this size (TPWD; unpublished data). Because inclusion of fish that were not fully recruited to the gear would underestimate the true population size, marked and recaptured fish < 107 cm were omitted. Population size was estimated after each year of data collection (2008 and 2009) and upon completion of the mark-recapture component of the study in June 2010. Because of the relatively low number of recaptures, confidence intervals were calculated assuming recaptures were approximately Poisson distributed (Chapman 1948, Seber 1982). Alligator gar abundance was also used to estimate density in both number of fish river-km^{-1} and number of fish ha^{-1}.

Although the primary assumption of a Schnabel multiple census estimator is a closed population (i.e., one with no immigration, emigration, recruitment, or mortality), it is often useful when these conditions are only approximately satisfied (Ricker 1975). Because alligator gar were sampled throughout the majority of the impounded reach where habitat is suitable, we considered immigration or emigration to be minimal. Although the mark-recapture effort occurred over nearly a three-year period, mortality and recruitment of this long-lived species was typically low and likely offset each other, thus satisfying those assumptions.

Angler exploitation was estimated from voluntary tag returns (i.e., without rewards or incentives) by anglers not associated with Kirkland's Gar Fishing Guide Service, which released all recaptured fish. In addition to unique tag numbers, tags included the words "research fish" and "if caught call" with a phone number. Angler exploitation was calculated for 2008 and 2009 by dividing the number of tags returned for fish ≥107 cm by the number of tags at large after adjusting for hooking mortality and tag loss. We also adjusted the number of tags returned assuming non-reporting or non-detection was 50%, which corresponded to the midpoint of values used by Binion et al. (2015). Similar to the population estimate, confidence intervals were calculated assuming observations were approximately Poisson distributed (Chapman 1948, Seber 1982).

Vital Rates

Sagittal otoliths ($n = 119$) were used to estimate alligator gar ages, and subsequently longevity, mortality, and growth in the study reach. Preparations and age estimation followed the methods described by Buckmeier et al. (2012). Otoliths were ground in the transverse plane, immersed in water to reduce reflection, and illuminated using a single-strand fiber optic filament. Year class was then estimated independently by two readers without reference to fish length. If the assigned year classes differed, a second independent estimate was provided by each reader. Following the second estimate, remaining discrepancies were settled using a consensus read. Ages were then calculated to the nearest 0.1 years by subtracting the peak hatch date (i.e., 1 June of the year the fish was

Table 1. Cumulative number of alligator gar ≥107 cm total length captured, marked (adjusted for tag loss and hooking mortality), and recaptured in the middle Trinity River, Texas, from August 2007 through June 2010. Annual population estimates were calculated using a Schnabel multiple census design. Exploitation estimates were based on voluntary angler returns of tagged alligator gar. Confidence intervals (CIs) assumed a Poisson approximation.

Year	Cumulative captured	Cumulative marked	Cumulative recaptured	Population estimate	95% C.I.s of population estimate	Exploitation	95% C.I.s of exploitation
2008	306	237	3	8413	2586–43224	2.9%	1.0–6.0%
2009	497	354	10	7903	4409–17712	4.0%	2.1–8.3%
2010	560	390	12	8365	5039–17637		

hatched) from the capture date and dividing by 365 days. Longevity was defined as the age to which 1% of the fish survived and was calculated as the age that corresponded with the 99th percentile of our age sample (Quinn and Deriso 1999). Annual total mortality was then estimated by assuming a type II survivorship curve (i.e., constant mortality) fit to represent 1% of fish reaching the estimated longevity (Ricker 1975, Hoenig 1983). Because the population has been fished, this mortality estimate includes both natural and fishing mortality. We described growth by fitting two alternative models (i.e., von Bertalanffy and power models) to length-at-age data (Katsanevakis and Maravelias 2008). The traditional von Bertalanffy growth model was used to represent an asymptotic growth function, while the power growth model represented non-asymptotic growth. In both equations L_t equals total length at age t. Both models were fit with the Excel Solver tool based on iterative least squares, and Akaike Information Criterion (AIC; Akaike 1974) and r^2 values were calculated and used for model comparison.

Results

Size Structure, Population Estimate, and Angler Exploitation

Size structure of angler-caught alligator gar from the middle Trinity River was broad, with fish ranging from 46 to 241 cm in length. Distribution of fish was fairly uniform across 15-cm length categories, particularly for alligator gar between 90 and 210 cm (Figure 2). Trophy-sized alligator gar (> 180 cm; Binion et al. 2015) were common and represented more than 23% of the sample.

Annual estimates of alligator gar (≥107 cm) abundance ranged from 7903 to 8413 during the three years of study, and annual angler exploitation ranged from 2.9% to 4.0% (Table 1). Exploitation was not calculated for 2010 because data collection only continued through June. Alligator gar (≥107 cm) density was estimated to be 26 fish river-km^{-1} (95% CI, 16 to 54 fish river-km^{-1}) and 0.8 fish ha^{-1} (95% CI, 0.5 to 1.6 fish ha^{-1}) in the final year of the study. All reported harvest of alligator gar in 2008 and 2009 ($n = 7$) occurred from May through September. In 2010, an additional three tagged alligator gar were harvested from April through June. Methods of harvest included bow ($n = 8$), rod and reel ($n = 1$), and trot lines ($n = 1$).

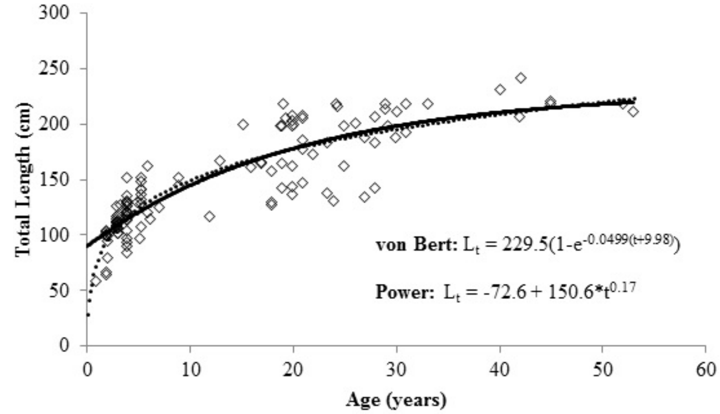

Figure 3. Growth equation estimates (von Bertalanffy = solid line; Power = dotted line; L_t = total length at age t) based on length at age of alligator gar captured in the middle Trinity River, Texas ($n = 119$).

Vital Rates

Age estimates for alligator gar ranged from 1 to 53 yrs (Figure 3). Subsequently, longevity was estimated at 52 yrs because > 1% of our sample lived to that age. Using this longevity, annual total mortality was estimated at 8.5% with a corresponding survival of 91.5%. Length at age was highly variable, and both the von Bertalanffy curve (AIC = 1851; $r^2 = 0.7639$) and the power growth curve (AIC = 1845; $r^2 = 0.7761$) provided similar fit to the majority of the data; however, the power growth curve modeled early length at age better than the von Bertalanffy growth curve (Figure 3). The AIC and r^2 provided similar support for both models, with the power model providing a marginally better fit.

Discussion

The characteristics of the middle Trinity River alligator gar population appear to provide high trophy potential relative to other populations. With the exception of the Mobile-Tensaw Delta in Alabama where Ferrara (2001) reported 24% of the population exceeded 180 cm and maximum age was 50 yrs, other populations were dominated by smaller, younger fish (Ferrara 2001, DiBenedetto 2009, Binion et al. 2015). Density of alligator gar was also higher in the middle Trinity River (0.8 fish ha^{-1}) compared to Choke Canyon Reservoir (0.5 fish ha^{-1}; Binion et al. 2015).

Truncated size structure could be indicative of higher fishing mortality in other alligator gar populations. For instance, in Lake Pontchartrain and the Bayou DuLarge, Louisiana, where commercial fisheries exist, alligator gar > 180 cm composed ≤ 3% of the population samples and maximum ages were only 26–28 yrs (Ferrara 2001, DiBenedetto 2009). In other systems, evidence of historic exploitation may still be evident in the current size and age structure. For example, in the Sabine National Wildlife Refuge, Louisiana, where commercial fishing continued until 1992, alligator gar > 180 cm made up about 11% of the population sample and maximum age was only 28 years (Ferrara 2001). Similarly, in Choke Canyon Reservoir, Texas, where commercial exploitation was high in the early 1990s following initial reservoir filling but has since ceased (TPWD; unpublished data), fish > 180 cm composed 5% of the population sample and maximum age was only 27 yrs (Binion et al. 2015). In both the Sabine and Choke Canyon populations, it is likely that the size and age structure were still rebuilding at the time of those studies and that in the following decades these populations may be more similar to the populations of the middle Trinity River or the Mobile-Tensaw Delta.

Differences in selectivity among sampling techniques can affect estimates of population characteristics. Past studies have used combinations of data from commercial fishers, recreational anglers, floaters (a type of jug line), and multifilament gill nets (Ferrara 2001, DiBenedetto 2009, Binion et al. 2015). While the current study relied heavily on angler caught fish (both rod-and-reel and bow), we are confident it provided useful data that adequately represented the population of alligator gar ≥107 cm in the middle Trinity River. *Post-hoc* analyses of the data provided by Kirkland's Gar Guide Service revealed no evidence of capture avoidance or size bias. For example, recapture rates were similar across years (range = 1.1% – 1.8%) and sizes of recaptured fish (mean TL = 133.2 cm, SD = 36.6 cm) were similar to the overall sample (mean TL = 143.1 cm, SD = 43.1 cm). In addition, sizes of fish provided predominantly by bow anglers for age estimation (mean TL = 147.9 cm, SD = 44.1 cm) were also similar to fish caught by the guide service (mean TL = 143.1 cm, SD = 43.1 cm).

Despite the difference in alligator gar density between the middle Trinity River and Choke Canyon Reservoir populations, current recreational angler exploitation was similar and low. Estimated exploitation ranged between 2.9% and 4.0% annually in the middle Trinity River compared to 0 to 2.3% annually in Choke Canyon Reservoir (Binion et al. 2015), falling within the range (≤5%) targeted by current TPWD alligator gar management. However, there is a limited commercial fishery on the middle Trinity River that is subject to the same 1 fish d^{-1} limit as the recreational fishery. None of our harvested tagged fish were reported from the commercial fishery, but recent commercial harvest data suggest commercial exploitation could be about 1.0% annually (2014 harvest = 82 fish; TPWD; unpublished data). Taken in combination, recreational and commercial harvest in the middle Trinity River could be approaching the 5.0% targeted maximum in some years.

Although the confidence interval for our final population estimate was relatively wide (5039–17,637 fish), it is clear that this population can only sustain an annual harvest of several hundred alligator gar ≥107 cm (i.e., 252–882 fish at 5% exploitation) to retain its current trophy characteristics. Our study design may not have fully adhered to the assumption of a closed population; however, any violations from mortality or recruitment were likely small. Because they are long-lived, alligator gar tend to have low annual recruitment and mortality with occasional episodic reproduction resulting in strong year classes. Our age data indicated no evidence of a strong year class that would have recruited to the population during the study period and considering that annual mortality was only 8.5% it is likely recruitment and mortality offset each other. This assumption is also supported by the lack of an increasing or decreasing trend in our population estimate which ranged from 7903–8413 fish over the three years.

Alligator gar vital rates in the middle Trinity River were generally similar to those reported for other populations. Longevity of 52 yrs was among the highest reported for alligator gar populations (e.g. Mobile-Tensaw Delta maximum age = 50 yrs; Ferrara 2001), but is likely typical of a population that has not been overexploited. Populations with reduced maximum ages are likely the result of high exploitation at some point in the distant (e.g., Binion et al. 2015) or recent (e.g., DiBenedetto 2009) past. The estimated annual mortality rate of 8.5% for the middle Trinity River was consistent with Ferrara's (2001) pooled mortality estimate for Alabama, Mississippi, Louisiana, and Texas of 9.3%. Similar to other studies, we found that growth was highly variable among individual alligator gar, and that although growth was rapid initially, it began to slow once fish reached about 110 cm (Ferrara 2001, DiBenedetto 2009, Binion et al. 2015). Both growth models we tested had similar support from our data (i.e., similar AIC values), but the power model provided a better estimate of growth at young ages. Partially due to low sample size at young ages, the fitted von Bertalanffy model gave an unrealistic growth trajectory of alligator gar for the first several years of life, predicting hatch at a size of 90 cm. In addition to predicting more realistic sizes at age for the first few years, the non-asymptotic nature of the power model may be more appropriate for describing growth of a very long-lived fish with indeterminate growth.

The current TPWD management goal for the Trinity River alligator gar population is to provide a unique trophy fishing opportunity and maintain the existing size structure and density. Based on our estimates of size structure, exploitation, and population vital rates, we are currently meeting this goal. However, because alligator gar are a long-lived species with variable recruitment, populations can be vulnerable to overfishing (e.g., Parent and Schrimi 1995, Boreman 1997, Jennings et al. 1998). Truncated size and age structure of commercially-fished alligator gar populations in Louisiana (Ferrara 2001, DiBenedetto 2009) provides further evidence of susceptibility. This necessitates a cautious approach to management, because recovery will be slow if overexploitation occurs (e.g., populations in the Sabine National Wildlife Refuge, Louisiana, and Choke Canyon Reservoir, Texas). We believe that current harvest levels in the middle Trinity River are sustainable. However, because regulations (i.e., 1 fish d^{-1} bag limit) do not limit entry, higher fishing effort could increase harvest above the targeted 5% maximum. Hence, more restrictive regulations (e.g., harvest quotas or a tag system) may be required in the future to maintain this unique alligator gar population.

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Literature Cited

Akaike, H. 1974. A new look at the statistical model identification. Institute of Electrical and Electronics Engineers Transactions on Automatic Control 19:716–723.

Binion, G. R., D. J. Daugherty, and K. A. Bodine. 2015. Population dynamics of alligator gar in Choke Canyon Reservoir, Texas: implications for management. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:57–63.

Bennett, D. L. and C. C. Bonds. 2012. Description of bowfishing tournaments in the Trinity River, Texas with emphasis on harvest of alligator gar. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 66:1–5.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes 48:399–405.

Buckmeier, D. L. and K. S. Reeves. 2012. Retention of passive integrated transponder, T-bar, and coded wire tags in Lepisosteids. North American Journal of Fisheries Management 32:573–576.

———, N. G. Smith, and D. J. Daugherty. 2013. Alligator gar movement and macrohabitat use in the lower Trinity River, Texas. Transactions of the American Fisheries Society 142:1025–1035.

———, ———, and K. S. Reeves. 2012. Utility of alligator gar age estimates from otoliths, pectoral fin rays, and scales. Transactions of the American Fisheries Society 141:1510–1519.

Chapman, D. G. 1948. A mathematical study of confidence limits of salmon populations calculated from sample tag ratios. International Pacific Salmon Fisheries Commission Bulletin II. New Westminster, British Columbia.

DiBenedetto, K. C. 2009. Life history characteristics of alligator gar, *Atractosteus spatula*, in the Bayou Dularge area of southcentral Louisiana. Master's thesis. Louisiana State University, Baton Rouge.

Ferrara. A. M. 2001. Life-history strategy of Lepisosteidae: implications for the conservation and management of alligator gar. Doctoral dissertation. Auburn University, Auburn, Alabama.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate morality rates. U. S. Fishery Bulletin 83:898–903.

Inebnit, T. E., III. 2009. Aspects of the reproductive and juvenile ecology of alligator gar in the Fourche LaFave River, Arkansas. Master's thesis. University of Central Arkansas, Conway.

Jelks, H. L., S. J. Walsh, N. M. Burkhead, S. Contrereas-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N.E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. J. Schmitter-Soto, E. B. Taylor, and M. L. Warren. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. Fisheries 33:372–407.

Jennings, S., J. D. Reynolds, and S. C. Mills. 1998. Life history correlates of responses to fisheries exploitation. Proceedings of the Royal Society of London B 265:333–337.

Katsanevakis, S. and C. D. Maravelias. 2008. Modelling fish growth: multi-model inference as a better alternative to a priori using von Bertalanffy equations. Fish and Fisheries 9:178–187.

Kluender, E. R. 2011. Seasonal habitat use of a leviathan, alligator gar, at multiple spatial scales in a river-floodplain ecosystem. Master's thesis. University of Central Arkansas, Conway.

Parent, S. and L. M. Schrimi. 1995. A model for the determination of fish species at risk based upon life-history traits and ecological data. Canadian Journal of Fisheries and Aquatic Science 52:1768–1781.

Quinn, T. J. and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, New York, New York.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Bulletin 191, Ottawa, Canada.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd edition. Charles Griffin and Company, London, United Kingdom.

Timmons, T. J. and M. H. Howell. 1995. Retention of anchor and spaghetti tags by paddlefish, catfishes, and buffalo fishes. North American Journal of Fisheries Management 15:504–506.

Winemiller, K. O. and K. A. Rose. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196–2218.